DOCUMENT RESUME

ED 393 793 SO 026 414

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TITLE Science and Art, Learning Packet.
INSTITUTION High Museum of Art, Atlanta, GA.
PUB DATE 94
NOTE 38p.; Accompanying 20 slides available from the High Museum of Art.
AVAILABLE FROM High Museum of Art, 1280 Peachtree Street, N.E., Atlanta, GA 30309 ($12.50).
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Art; *Art Criticism; *Art Education; Art History; *Color; Elementary Secondary Education; *Light; *Science Activities; Science Education; Science Experiments; Visual Arts
IDENTIFIERS *Perspective (Visual Arts); *Space (Visual Arts)

ABSTRACT

Science and art have much in common. Artists as well as scientists carefully observe and communicate their subjects. Throughout time, artists have been involved in experimentation, an important scientific method which can lead to new discoveries. Both scientific developments and the ongoing history of art are cumulative. This learning packet is an introduction to two themes related to both science and art: "Space and Perspective" and "Light and Color Theory." Slide narrations for the 20 packet slides are given. Classroom activities include exercises and experiments in "Perspective and Illusion"; "Experiments with Light"; and "Experiments with Color." Contains a glossary and a 17-item bibliography. (MM)

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SCIENCE & ART

Learning Packet

Written by Carla Michalove Singer

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INTRODUCTION

This learning packet will introduce painting as a science. *Science and Art* is a tour of the High Museum of Art which will illustrate how pictures are like artists' experiments. The art museum setting provides an ideal environment to learn about both disciplines, science and art.

Science and art are often thought to be mutually exclusive disciplines. Science is considered the study of natural phenomena while the dictionary defines art as the "human effort to imitate, supplement, alter, or counteract the work of nature." Strictly defined, science and art are opposites. Science studies the natural world and art is a study of the artificial world.

Renaissance artist and scientist Leonardo da Vinci believed that "art and science were two closely related activities, two means for describing the physical world." Leonardo wrote in his notebooks, "First study science, and then follow with practice based on science....The youth ought first to learn perspective, then the proportions of everything...then from nature...then for a time he should study the works of different masters; then make it a habit to practice and work at his art."

Science and art have much in common. Artists as well as scientists carefully observe and communicate their subjects, whether they are botany, anatomy, physics, or human character. Artists must understand certain scientific principles in order to make the best use of their materials. Scientists fit the above definition of art when they alter nature to clone embryos, invent new substances, or counteract gravity with rockets.

The word science comes from a Latin word meaning "to know." We come to art museums wanting to know more about art. We can apply scientific methods such as observation, identification, and description to learning about art. We can use human-made art objects to observe scientific phenomena.

Throughout time, artists have been involved in experimentation, an important scientific method which can lead to new discoveries. Both scientific developments and the ongoing history of art are cumulative.

Artists such as Seurat, Albers, and Flavin, to name only a few, have experimented with techniques and invented new media for their artwork:

- Georges Seurat studied optical theory and was the first to experiment with pointillism, a way of combining primary color dots that blend together when the painted canvas is viewed at a distance.

- Josef Albers experimented with the effect of placing pure color blocks next to each other in his minimalist oil paintings. He was fascinated by the resulting visual vibrations and illusions.

- Dan Flavin uses light as if it were paint by installing colored fluorescent light as his artwork.

This learning packet, "Science and Art," is an introduction to two specific themes related to both science and art: SPACE and PERSPECTIVE and LIGHT and COLOR THEORY.

By studying space and perspective we can become aware of how our eyes perceive distance. We can learn techniques artists use in paintings to make objects look further away. We automatically "read" paintings for distance and depth according to certain criteria accepted in our culture.

By studying light and color theory, we can see how artists use scientific information when manipulating pigment to represent color and light in oil paintings. Artists use the appearance of light and color to relay information about texture, size, shape, and space.

In 1836 landscape painter John Constable wrote "Painting is a science, and should be pursued as an inquiry into the laws of nature. Why, then, may not landscape be considered as a branch of natural philosophy, of which pictures are but experiments?"

While making art is sometimes considered to involve a more intuitive process, looking at art and trying to understand it in an art museum is more clearly like science, a "knowledge gained through experience."

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For more information on the High Museum of Art's resource materials and services for students and teachers, please contact:

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TO THE TEACHER

This learning packet contains slides with narration as well as classroom activities and experiments dealing with the two themes: SPACE and PERSPECTIVE, and LIGHT and COLOR THEORY. The slides should be presented before the museum visit. You may wish to conduct the experiments and activities after your museum visit as follow-up. All are simple and require little in the way of materials. Remember that this packet is intended as a guide to class discussion rather than a lecture script. Please read the information in advance and make whatever additions or deletions will make it most useful for your class. By all means include references to any relevant materials or experiences with which your students are familiar.

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LIST OF SLIDES

1. Jacobello del Fiore (Italian, active 1394-1439)
   Madonna of Humility, ca. 1395-1405
   Tempera and gold leaf on panel
   Purchase with Friends of Art Fund
   42.15

2. Giovanni Bellini (Italian, ca. 1426-1516)
   The Madonna and Child, ca. 1510
   Oil on panel
   Samuel H. Kress Collection
   58.33

3. Frederic Bazille (French, 1841-1870)
   Beach at Sainte-Adresse, 1865
   Oil on canvas
   Gift of the Forward Arts Foundation in honor of Frances Floyd Cocke
   1980.62

4. Seymour J. Guy (American, 1824-1910)
   Dinnertime, n.d.
   Oil on canvas
   Lent by the West Foundation
   EL 154.1984

5. John Henry Twachtman (American, 1853-1902)
   Along the River, Winter, ca. 1889
   Oil on canvas
   J. J. Haverty Collection
   49.28

6. Henry Inman (American, 1801-1846)
   Tai-O-Mah, ca. 1831-33
   Oil on canvas
   Anonymous gift
   1984.174

7. George Inness (American, 1825-1894)
A Bit of the Roman Aqueduct, 1852
Oil on canvas
Purchase with funds from the Members Guild and through Exchange
69.42

8. John F. Kensett (American, 1818-1872)
Camel's Hump from the Western Shore of Lake Champlain, 1852
Oil on canvas
Gift of Virginia Carroll Crawford
76.67

9. Arshile Gorky (American, born in Armenia 1905-1948)
Garden in Sochi, 1940-41
Gouache on board
Purchase with bequest of C. Donald Belcher
1977.50

10. George Henry Hall (American, 1825-1913)
Bric-a-Brac from Damascus, Rome and Seville, 1880
Oil on canvas
Lent by the West Foundation
EL21.1981

11. Richard Estes (American, born 1935)
Supreme Hardware, 1973
Oil and acrylic on canvas
Gift of Virginia Carroll Crawford
1978.119

12. Giovanni Maria Benzoni (Italian, 1809-1873)
The Veiled Rebekah, 1864
White marble
Gift of Mrs. John B. Gordon
27.23

13. Charles-Francois Daubigny (French, 1817-1878)
Banks of the Oise River, 1875
Oil on canvas
Purchase with a bequest of Lenora Raines and general funds in honor of the 20th anniversary of the Forward Arts Foundation
1985.21

14. Jerry Gordon (American, born 1949)
The Breakers Hotel, Palm Beach, Fla. 1978, Printed 1979
Cibachrome print on paper
Gift of Lucinda W. Bunnen
1983.30

15. Diffraction Grating Slide

16. John Culverhouse (American, 1849-1891)
Moonlit Market, 1874
Oil on canvas
Gift of the James Starr Moore Memorial Foundation
1985.20

17. Claude Monet (French, 1840-1926)
Houses of Parliament in the Fog, 1903
Oil on canvas
Great Painting Fund purchase in honor of Sarah Belle Broadnax Hansell
60.5

18. Giovanni Battista Gaulli, called Baciccio (Italian, 1639-1709)
Abraham's Sacrifice of Isaac, ca. 1685-90
Oil on canvas
Gift of the Samuel H. Kress Foundation
58.31

19. Mark Rothko (American, 1803-1970)
Number 73, 1952
Oil on canvas
Gift of the Mark Rothko Foundation, Inc.
1985.27

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20. Martin Johnson Heade (American, 1819-1904)
Twilight, ca. 1886
Oil on canvas
Gift in memory of Howard R. Peevy from his wife
73.51

All slides except diffraction grating represent artwork on loan to or from the permanent collection of the High Museum of Art.

SLIDE NARRATION

The earliest known artworks are the cave paintings of France and Spain. They give us a record of early man's extraordinary powers of observation. Before these pictures could be painted, early man had to figure out what materials to use. Some rocks can be used to make pictures and some can't. The ones that can are called pigments.

Discussion Ideas:

1. How would you find out what rocks to use for drawing?

2. If you wanted to make these rocks into paint, how would you figure out to grind them up and what to mix them with?

When you have an idea, try it out, and pay attention to the results, you are doing an EXPERIMENT. Experiments are how scientists study nature.

Methods of observation have changed through the centuries. We can imagine the prehistoric "scientist" smashing a rock to find out about it. The more sophisticated medieval chemist applied heat or an acidic solvent to determine the composition of a substance. Today scientists study light that has traveled through space for millions of years so they can learn about the gases that make up distant planets. In all these examples, the research procedure is to break the object under investigation into its component parts, and to study each part separately. We call this ANALYSIS.

Analysis is an activity that scientists and artists have in common. The artist must choose a subject, decide what to show about it, then figure out how to use the available materials to represent the subject. At some times in history, it seemed very important for artists to try to show exactly how things look. For other periods, that kind of close matching of appearances just didn't matter.

We are going to be doing some analysis of the works of art in these slides. We'll be looking at some of the decisions the artists made. One of the ways we tell different styles of art is by what the artists at that time thought was important. For example, to the people of the Middle Ages, it was more important to show the majesty and power of a king than to show exactly what a particular king looked like.

Note to the teacher: If you wish to discuss Light and Color, skip to Slide #10.

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SPACE AND PERSPECTIVE

SLIDE #1: Jacobello del Fiore, *Madonna of Humility*

Christian subjects were by far the most popular in Europe for several hundred years after Christianity became the main religion.

Discussion Ideas:

1. What is the subject of this painting? Name what you see.

2. Do some parts of the picture seem to be in front of others, even though you know the painting is flat? Name the things that seem to be closest.

In analyzing the way we see, one of the first things artists learned was that when we see all of one object but only part of another object, the whole one is seen as being "in front of" the incomplete object. This is called OVERLAPPING. You have already pointed out some examples of overlapping in this painting. The overlapping of the right arm and leg of baby Jesus is what makes it look like his mother is holding him.

3. What about thi[illegible]st doesn't look quite right? Does the baby Jesus really seem to be standing on Mary's lap? [He seems to be floating in the air in front of her rather than resting his weight on her leg.]

This work was painted in the Late Middle Ages when the artists' major concern was with telling the Christian story and not with showing us exactly how things look.

4. What else about this painting is different from the way things really look? What part of the painting looks like no place on earth? [the gold background] What part looks like it is on the earth? [the field] Where do you think the Madonna and Child are supposed to be?

Toward the end of the Middle Ages, artists began to study the world they could see around them. Look at the plants in the field. Are they all the same? Jacobello shows several different kinds of plants in great detail.

This type of botanical illustration became important to art and science in the next period of European history, the Renaissance. The great Italian Renaissance artist-scientist-engineer, Leonardo da Vinci, wrote an essay [Treatise on Painting] in which he said Art is Truth and Truth is Science. Many of the Renaissance artists were

also scientists. They believed that if art was to be truthful (accurate), it had to be scientifically exact. The artist should learn the scientific truth before starting the work of art. And the work of art should show the viewer the scientific Truth.

The representation of space was the artists' greatest concern in the art of the Renaissance. Renaissance painters wanted their paintings to look like a view through a window, with the picture frame as the window frame. They used PERSPECTIVE to help create a sense of space on the flat surface of the painting.

SLIDE #2: Giovanni Bellini, *The Madonna and Child*

Discussion Ideas:

1. What does this Italian painting from about 100 years later have in common with the Jacobello painting? [the subject]

2. What are some of the major differences? [figures more solid, gold background has been replaced by a natural setting; child looks away]

It's obvious that painters learned a great deal in this century. Imagine the parts of this painting as three flat layers that have been stacked like playing cards. Each of the flat layers is called a PLANE. These separate planes organize the picture space into three parts:

3. Which part of the picture seems closest to you? [the wood at bottom] Which part seems farthest away? [blue water].

The FOREGROUND is the part that looks like it's just beyond your (the viewer's) space.

4. What is in the foreground? [ledge, people]

The BACKGROUND is the layer that seems the farthest away, what we think of as being in the "back" of the picture.

5. What is in the background? [landscape] What leads your eye deep into this vast landscape? [road]

   The MIDDLEGROUND is exactly where its name suggests, between the other layers, or planes.

6. What is in the middleground? [curtain]

When we look at this painting, it seems that Mary is looking right back at us. When a figure in a painting does this, it is called an ENGAGED EYE. An engaged eye is a kind of bridge between our space and the space in the picture.

You might notice that the colors are more glowing than the earlier painting. This is due to another way in which science can affect art: new kinds of materials. Older paintings were painted with tempera, which mixes egg yolk with pigment. This painting, and most later ones, was painted with oil paints that substitute linseed oil for the egg yolk.

SLIDE #3: Frédéric Bazille, *Beach at Sainte-Adresse*

In this landscape painting, the space seems to go back a long way. One of the reasons for this is the size of the boats.

Discussion Ideas:

1. Which boat seems closest? [bottom right] Which seems farthest away? [upper right]

Hold your fingers up to measure the size of each boat and compare the difference. Bazille is using two "tricks" of perspective here: We imagine that in "real life" the boats would be the same size. Since one is smaller, we see it as being farther away. Things that are smaller seem farther away. This is called DIMINUTION OF SCALE or SIZE PERSPECTIVE.

2. What part of the water seems farthest away?

Another factor at work is ELEVATION, a very important depth cue. The horizontal line across the middle of the painting, where the sky meets the land and the sea, is called the HORIZON. In a picture of a landscape the horizon is always higher than the foreground. Objects that are higher or farther from the bottom of the picture always appear to be a greater distance away.

You can see how much stronger the illusion of space becomes when artists combine several tricks of perspective in a painting!

SLIDE #4: Seymour J. Guy, *Dinnertime*

This small painting was made in America several hundred years after the painting we saw of the Madonna and Child in front of the green curtain—painted by the artist Bellini. You will notice many things about it that are very different. Bellini's Madonna is large and fills up a lot of the space. This makes her very important in the painting.

Discussion Ideas:

1. What about the figure of the woman in this farmyard? Notice the size of the woman. Does she seem to be the main subject of the painting? Is she in the foreground, middle, or background? [middleground]

2. What do you think the artist is most interested in showing us? [the space and the light] The subject of this painting is the time of day in this particular place.

This painting is a good one to look at a system of geometry that was developed in the 16th century to create the illusion of space in painting. It has been used ever since by artists who want to paint like a view through a window.

Have you ever noticed that if you look down railroad tracks, the two sides seem to get closer as they get farther away? We know the lines are actually parallel, which means they never meet, but it still appears that the sides of tracks come together at the horizon.

When artists use LINEAR PERSPECTIVE, they arrange parallel lines so that they seem to "move" diagonally backward through space to meet, or converge, at the horizon. The point where these lines meet is called the VANISHING POINT.

If you were to extend all the diagonal lines Guy uses for the road, the walls, doors and windows, they would all come together at a vanishing point. We cannot see the horizon in the picture because there is something right in front of the vanishing point.

3. What is in front of the vanishing point? [the barn]

All the lines in the picture point away from the figure, but something brings our attention to her. What? [the light] Artists know that colors that are lighter or brighter look closer to the viewer. Even though the woman in his picture is quite small, Guy uses the bright white of her apron to be sure we look at her.

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4. What did he do to make this white stand out even more? [He put dark shadows in the foreground.]

Did you ever try to draw with white chalk on white paper? It's a lot harder to see the drawing than if you draw on black paper. This is the effect of CONTRAST. We can see the moon at night because of the contrast with the dark sky. It is shining in the daytime, too, but we usually can't see it in the sunlit sky. The illusion of deep space in *Dinnertime* is stronger because Guy attracts our eyes back into the middleground with the white apron.

SLIDE #5: John Henry Twachtman, *Along the River*

Discussion Ideas:

Even though the painting is so simple, Twachtman has made use of several of the elements of perspective we've discussed. That is why we see this scene as a road moving back through a snowy landscape and not as two zigzag lines on a white rectangle.

1. What kinds of perspective has he used? [vanishing point, linear perspective, elevation, diminution of scale]?

2. What is the darkest part of the picture? [the lines of the road and the shapes on the horizon].

Twachtman uses contrast in brightness in a different way than Guy. He counts on the fact that our brain sees brighter things as closer; darker and shadowy things look more distant. This is called VALUE PERSPECTIVE. In this mostly light white picture, the darker gray shapes look farther away. They are also higher, and smaller than the road.

SLIDE #6: Henry Inman, *Tai-O-Mah*

Discussion Ideas:

1. What is the main shape of the head in this portrait of a Fox Indian leader? If you look at it as a flat shape, it is an oval. But the artist did not want it to look flat.

2. Which part of the face looks closest to you? [forehead, top of nose, chin] What color has been used to paint these parts? [white] The lightest areas are called

HIGHLIGHTS. Which part is darkest? [black under chin, shadows around eyes, nose and mouth] The darker areas are called shadows.

We've already talked about the fact that light colors, like white, seem to ADVANCE, or come forward, while dark colors, like black, seem to RECEDE, or move back into space. Artists use this fact to make the head seem like a solid egg-shape in space rather than a flat oval. This careful manipulation of color values from light to dark is called MODELING. It gives objects the illusion of three-dimensionality even though they are really on a flat picture surface.

SLIDE #7: George Inness, *A Bit of the Roman Aqueduct*

Discussion Ideas:

1. Which part of this landscape painting seems closest to you? [the ground at the bottom] What colors did the artist use in that section? [brown, warm colors] Which colors are used in the part that seems most distant? [Blue]

For a long time artists have known that when we look out at a landscape, things look more and more blue as they approach the horizon. How has Inness made use of that phenomenon, called ATMOSPHERIC PERSPECTIVE? He put the warm, deep colors of the earth in the foreground and the light, hazy blue of the mountains in the background.

You might also notice that there is a lot of detail in the lower part of the painting, where you can see every rock.

2. What happens to this detail as you look up to the land that is supposed to be far away? Inness has made changes in the DISTINCTNESS of various parts. Since we can see things better when they are closer to us, sharp edges and clear details in painting imply closeness. Artists paint distant objects less distinctly.

SLIDE #8: John Frederick Kensett, *Camel's Hump from the Western Shore of Lake Champlain*

Let's use this painting for a kind of final exam. Look closely to find examples of all the visual tricks Kensett has used to fool our brains into thinking we're looking into a deep landscape. Look for:

(1) OVERLAPPING (whole looks in front of partial image)
(2) SEPARATION INTO PLANES (foreground, middle, background)
(3) DIMINUTION OF SCALE (larger looks near; smaller looks far)
(4) ELEVATION (lower looks near; higher looks far)
(5) LINEAR PERSPECTIVE (diagonal lines meet at vanishing point)
(6) MODELING (light looks near; dark looks far)
(7) ATMOSPHERIC PERSPECTIVE (bright colors look near; hazy blue looks far)
(8) DISTINCTNESS (sharp details look near; blurriness looks far)
(9) COLOR (warm colors advance; cool colors recede)

There is an old expression, "Seeing is believing." But as we have seen, artists have many ways of distorting our perceptions so that our eyes fool us. In the years following 1500, techniques of perspective spread rapidly throughout Europe, linking art to science by a common interest in geometry. But as soon as artists mastered the technique, they stopped working in a strictly mathematical way. Later artists studied the rules of perspective, but did not plan every painting by measuring. Michelangelo said that the true artist must possess "compasses in his eyes," rather than relying on mechanical calculation.

The mathematical rules of proportion and perspective suited the Renaissance artists because they wanted to paint with scientific exactness. But in the 20th century, many artists were not interested in fooling the viewer with paintings that looked like views through a window.

SLIDE #9: Arshile Gorky, *Garden in Sochi*

One of the main ideas of Modern Art is that a painting is an arrangement of lines, shapes, and colors on a flat surface AND IT DOESN'T HAVE TO PRETEND TO BE ANYTHING ELSE!

In Gorky's painting of a garden we may see shapes that remind us of butterflies, rocks or trees. But the artist has not tried to show us the scene the way camera would record it. Instead, he uses the elements of art to share his personal memory of the garden he remembers from childhood. The shapes are more like the ones in dreams than like the observations of a scientist.

You may find that some of the principles of illusion we discussed are at work in this painting. The shapes that are higher may seem farther away. Can you find other examples? Gorky has not used these rules to try to fool our eyes. Our brains just work that way!

Every painting is, as the modern artists claim, an arrangement of lines, shapes and colors on a flat surface. We can look at this arrangement and take it apart to try to understand exactly what the artist has done. But looking at each part will not necessarily tell us everything about the whole work.

The geometry of perspective imagines the space of a picture as the inside of a box. The idea of a box is important, too, because it can teach us something about using analysis when we look at art. You can build a box from six square, flat pieces of wood. Each of these pieces has a top, a bottom and shallow sides. But none of the parts can do what a whole box can do. None of the parts can contain something. It is only when we put all the parts together in a certain way that we get a whole new thing–a box that can hold something.

The space created by all the parts working together disappears when we take apart a box. The special beauty of a work of art cannot be completely explained by analyzing all its components.

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LIGHT AND COLOR THEORY

LIGHT

Medieval scientists analyzed thousands of substances, but light remained a puzzle. By experimenting, they learned certain things about the way light behaves. They knew that light travels in straight lines. They could see that light passes through, or is TRANSMITTED by, some surfaces and that it bounces off, or is REFLECTED, from others. They observed that light is bent, or REFRACTED, when it passes at an angle into or out of transparent substances like glass or water.

See the Light Experiments for instructions on observing these principles in the classroom.

SLIDE #10: George Henry Hall, *Bric-a-Brac from Damascus, Rome and Seville*

When light strikes an object, it may be reflected, transmitted, or absorbed. Everything reflects at least some light. The reflection of light is very important. If the things around us didn't bounce light back to our eyes, we couldn't see them. We ordinarily see objects by DIFFUSE REFLECTION, which tells us about the shape, size, color, and texture of objects.

Reflection varies with the type of material and that is what the artist is showing us in this still life.

Discussion Ideas:

1. Which things in the still life look the "shiniest"? [the metal helmet, bowl, plate, and porcelain vases] How does Hall show this? [by using white and the lightest colors]

Polished metal reflects most of the light, absorbs only a little, transmits practically none. Like many artists, Hall knew that light colors seem to come forward and dark colors seem to recede, or go back. By using white and light colors, he creates the illusion of lots of light bouncing back at us from the metal and porcelain objects in his painting.

Unlike metal, wood absorbs much of the light, reflects very little, and transmits practically none.

2. What colors does Hall use for the wooden things in the picture? [middle to dark browns and black] How else does the artist use color to show us the different textures of the objects in this still life?

Reflection is like kicking a ball against a wall. If you kick it sideways, it will bounce away from you. In diffuse reflection, light leaves the surface at many different angles. The rougher the surface, the more numerous the angles. When light strikes a smooth surface, like a mirror, it is reflected back at the same angle. This is like kicking a ball straight at a wall; it comes right back to you. This is why instead of seeing the surface of the mirror, we see the objects reflected in it.

Since most reflection is diffuse, mirrors are a special case. Many painters have been intrigued by the challenge they present.

SLIDE #11: Richard Estes, *Supreme Hardware Store*

Discussion Ideas:

1. What in this painting acts like a mirror? [the store windows] What do you see reflected in the windows? [the buildings and signs on the other side of the street]

In this clever composition, the artist Richard Estes is able to show both sides of the street by only painting one side. He is also able to show off his understanding of light and reflection.

While most surfaces reflect or absorb most of the light that strikes them, TRANSPARENT materials mostly TRANSMIT, or let light pass through.

2. Can you name some examples of transparent materials? [glass, movie film, cellophane, dragonfly wings, plastic]

Like mirrors, the representation of transparency poses special problems for artists. We have been looking only at paintings, so let's look at a sculpture for a change.

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SLIDE #12: Giovanni Maria Benzoni, *The Veiled Rebekah*

Discussion Ideas:

1. What in this sculpture looks transparent? [the veil] What does it seem we are seeing through the veil? [the woman's face, clothes, hair, body] Everything in the sculpture is made of the same material. Do you know what material? [white marble]

So that means the veil was carved from the marble along with the rest of the figure. Everyone asks the same question about this sculpture: HOW did he do that?!

If you look, it is not hard to see the REFRACTION, or bending, of light when it crosses the boundary between two different materials, like air into water. Put a straw in a glass of water and look at it from the side. The straw will look like it bends at the point where it enters the water. To understand why, you have to know a little more about light.

For a long time, scientists thought light traveled in little particles like tiny grains of dust. It wasn't until the 19th century that Thomas Young proved that light is energy traveling in WAVES. If you drop a stone into a pool of water, it will make waves. The waves will have the shape of rings, each one followed by another, bigger one, until they are stopped by the edges of the pond. You can observe this yourself in a bowl or pan of water.

Many things in nature move in this way, including sound. Light waves move so fast, we can't see it. The speed of light is more than 186,000 miles per second.

Now that you know light moves from place to place in waves, you can imagine that it goes at a certain speed. Just as you can drive faster on the highway than near a school, light travels at different speeds depending on where it is.

Light moves fastest in a vacuum, like space, where there is nothing to slow it down. It moves almost as fast through air. But when light moves from air into water it slows down. Unless it goes straight in at a right angle, light entering water is bent. This is why the straw in your glass seems to bend.

SLIDE #13: Charles-Francois Daubigny, *The Banks of the Oise River*

Daubigny [DOH-been-yee] was one of the most famous landscape painters in France in the mid-19th century. His specialty was scenes depicting water. Daubigny traveled through the rivers of the French countryside on his boat that was set up as a studio.

Discussion Ideas:

1. How does Daubigny show us that light is refracted when it moves from air to water? [the reflections of the trees are slightly offset rather than being directly underneath]?

2. How else does he show us his close observation of the reflections in the water? [the reflected trees are painted in less detail and look fuzzier than the trees in the landscape.

Not long after the time of Daubigny, artistic ideas underwent a big change. Since the Renaissance, artists had been trying to represent the world in pictures as though the picture frame was a window. Once the camera was invented, artists could let photography take over that job. In modern art, artists began to use the language of art to express their own ideas rather than the way things look.

SLIDE #14: Jerry Gordon, *The Breakers Hotel, Palm Beach, Fla.*

Because the world shown in an artist's work is a made-up world, many artists decided to make up their own rules. Like Daubigny, photographer Jerry Gordon is exploring the refraction of light in the water. Also like Daubigny's painting, we see some things in the air and some in the water. But a few things about this photograph are surprising.

Discussion Ideas:

1. Where was the photographer when he took this picture? [under the water in a hotel swimming pool] Name some things that are under the water. Name some that are out of the water. What seems out of place?

Some of the pieces here don't fit together right. We know light bends when it moves from air to water, but it doesn't bend THIS much!

Gordon has put humor in his photograph by moving parts around to exaggerate one of the phenomena of light. Just as Alice discovered when she went through the looking glass, the rules of another world are not necessarily the same as the ones we know. Because artists create a personal world through their art, they are free to make up any rules they want.

COLOR

In 1672 the great scientist SIR ISAAC NEWTON published a book about his scientific experiments with light and color. By passing light through a triangular glass prism, Newton was able to show that all the colors of the rainbow come from white light. You can use the DIFFRACTION GRATING in your slide set to show the same thing by shining the white light of the slide projector through it. You should see the colors of the rainbow on your screen.

Newton named this set of colors the "spectrum." They include red, orange, yellow, green, blue, indigo, and violet. By using a second prism, Newton was able to prove that white light is actually made up of colored lights. He analyzed the light by breaking it up and then putting it back together. Newton's theory of light and color explained that the different colors of light can be separated this way because each color is refracted (bent) to a different degree by the glass of the prism.

You can do a simple experiment to understand the way Newton's experiment worked. If you lay a closed paperback book on a table and try to count the pages, you can't see them because they are so close together. The side of the book will seem solid. But if you bend the book over the side of the table, you will be able to see the edge of each page. Now you can count them. When you finish counting, you can flatten the book and it will look solid again.

When the first prism bent the ray of light, all the colors of the spectrum were revealed in the same way the book showed its pages. When Newton passed the dispersed light through the second prism, he put it back together to make white light. Without light there would be no color.

SLIDE #15: Diffraction Grating

SLIDE #16: Johann Mongels Culverhouse, *Moonlit Market*

Culverhouse's painting of an open air market in Albany, New York, at night shows his understanding of the fact that we can only see color with light.

Where do you see the colors in the painting? [near the lights from the candles and the moon] What parts of the painting are black? [the building silhouettes, the backs of people facing towards the candles]

2. Imagine all the candles in the picture were blown out. How would the painting change? [it would be all black except for the light from the moon]

Things appear to have color because of what they do to white light when it hits them. Leaves look green because they reflect green light and absorb all other colors. Black objects absorb all seven colors of the spectrum. From space, the sky appears black. From the ground the sky looks blue because of SCATTERING. When white sunlight hits the atmosphere of the earth, the shortest wavelengths, the blue ones, break off from the other colors and are scattered in the air. As Newton observed, once light is separated in this way, it becomes visible. So the sky looks blue on a sunny day.

SLIDE #17: Claude Monet, *Houses of Parliament in the Fog*

The French Impressionist painter Monet was one of the most careful observers of the changing effects of light and atmosphere in the history of art. He really understood that we see only by means of reflected light. His goal as an artist was to paint exactly what he could see without using the information he knew about things.

Discussion Ideas:

1. The Houses of Parliament in London are very large government buildings designed in 1835 and built in the years following. What do you think they are made of? [stone] They are stone buildings decorated in the Gothic style, which is also why they have a lot of towers and spires. Do they look like heavy stone buildings in Monet's painting?

Monet KNEW what the buildings looked like from up close on a clear day. But what he shows us in this painting and many others like it, is what the buildings LOOKED LIKE at a particular moment on a foggy winter day.

Just as the blue light is scattered by air, it is even more scattered by the droplets of water in fog.

2. How does Monet show this in his picture?

Over all the picture looks blue and we can see only the vague silhouettes of the boat and buildings. Fog gives an exaggerated version of something artists often use to create a sense of distance in paintings, ATMOSPHERIC PERSPECTIVE.

The greater the distance between us and the thing we're looking at, the more blue is scattered into the lens of our eye. That is why when we look out at a far away landscape, it looks like a hazy blue.

SLIDE #18: Giovanni Battista Gaulli, *Abraham's Sacrifice of Isaac*

In some ways this painting is almost the opposite of Monet's Houses of Parliament.

Discussion Ideas:

1. What are some of the ways in which it is different? [it tells a story, has lots of detail] Which part of the picture looks like it's farthest away? [blue mountains] How has the artist used the atmospheric perspective we just mentioned? [The distant landscape becomes blue and shows less detail]

Let's look at something else that the color of this painting and the Monet have in common. If you bend the line of colors that make up the spectrum so that the ends touch, you will have a color circle. Three of the colors cannot be made by mixing other colors and are called PRIMARY, or first, colors. These primaries are different in pigments and light. Since artists work mostly with pigments, that is what we will look at.

The primary colors of pigments are red, yellow, and blue. As shown on your page with the color circle, or wheel, the three primary colors make up a triangle. Between each two primaries are the SECONDARY colors you can make by mixing them: red and yellow make orange; red and blue make purple; blue and yellow make green.

Pick any primary color and draw a straight line across the circle to the opposite side. There you will find the COMPLEMENTARY color that contains the other two primaries. For example, the complement of blue is orange. Find the complements of red and yellow. Complementary colors enjoy a special relationship. When they appear

next to each other, they each make the other stand out more strongly and at the same time they balance each other.

Let's look at the painting again.

2. What are the colors of Abraham's skin and clothes? [They are different kinds of orange]

When he chose to place the mostly orange figure against the blue sky, the artist knew that it would stand out more. As with foods, some combinations go together better than others. Peanut butter and jelly are better than peanut butter and pickles. By combining blue with orange, Gaulli was also following the rules for harmonious color combinations.

Take a minute to look back at the Monet painting. How has he used the complementary color harmony of blue and orange?

SLIDE #19: Mark Rothko, *Number 73*

We have seen that colors affect each other when they are placed side by side. If orange is next to yellow, the orange will appear redder and the yellow will look greener. This is called SIMULTANEOUS CONTRAST.

Discussion Ideas:

1. What is the subject of this painting? [colors and shapes create a mood]

Many artists in the 20th century chose to be honest about the fact that a painting is an arrangement of lines, shapes, and colors on a flat surface. Instead of a title, Rothko gave this work a number. A number doesn't influence what you think about when you look at the painting. Often these abstract paintings explore art ideas like the way colors affect each other. That is what Rothko has done in this painting and many similar works. Just imagine how different Number 73 would look if you put the purplish-red shape at the top and the yellow shape at the bottom.

Colors have the power to bring out feelings and associations in the viewer. Many people find blue to be soothing and red to be exciting. Colors can even change our blood pressure! Colors can have different meanings in different cultures. In Western cultures, black is a funeral color. In China mourners wear white. Interior designers know and work with the emotional aspect of colors. So do artists.

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SLIDE #20: Martin Johnson Heade, *Twilight*

Mark Rothko used color and their relationships in an abstract way to create a mood in the viewer. Martin Johnson Heade was also interested in creating a mood.

Discussion Ideas:

1. How do you feel when you look at this picture? Does it seem more like the mood you would want to be in to play a ballgame or to lie down for a nap?

Heade was one of the American artists of the 19th century that art historians have called "The Luminists" because they were so interested in depicting light in their paintings. If you think about it, most of the works we looked at have the source of light outside the picture. Only Culverhouse showed us where the light was coming from in his painting of a market at night. The luminists usually placed the source of light within their pictures.

2. Where is the source of the light in Twilight? What does Heade show us about the special qualities of light as day turns into night?

To the luminists, light was a symbol of the Divine Spirit in nature. To Monet, light was the physical energy that allows us to see the world. To Richard Meier, the architect of the High Museum of Art, and many others, light means understanding and knowledge. That is what cartoonists mean when they use the symbol of a light bulb to show a character getting an idea.

The science of light and color can help artists in their work. And we can use our knowledge of science to understand some aspects of the works of art we enjoy. Like the scientist, we can use the process of analysis to look at the components, the parts, of a painting or sculpture.

CLASSROOM ACTIVITIES

PERSPECTIVE AND ILLUSION

- Thinking about the third dimension in art is easier if you have some real objects to look at. Find some examples of flat circles (plastic can lids, paper disks), cylinders (cans, paper towel rolls, tootsie roll candies), and spheres (balls, oranges). Put these on a table together. Try to draw them. Make two other collections: triangles and pyramids; squares and cubes.

- Looking at a train moving away, would caboose or engine seem larger? Illustrate this idea in a drawing or photograph.

- Put half the class in a line with two feet between each student. The other half of the class should come one at a time to stand on a designated spot which is six feet from the first student in line, eight feet from the second, etc. Ask each student on the spot to measure a specified classmate with the distance between two fingers. Maintaining that finger position, record it on paper. Start with the first student in line and continue to the end. Measure each of these lines to find out the diminution of scale that is perceived. Have each student make a drawing illustrating this principle.

- Photocopy a page of large-sized text and give one to each of the students in the line. Ask students to stand on the designated viewpoint and try to read as many of the signs as possible. At what point do they become illegible? Is it the same for every viewer? Ask someone who normally wears glasses to try without their glasses.

- Look at the page illustrating two landscapes. (1) Give each student a piece of paper and ask them to draw a horizontal line near the center. Ask the students to cut out five each of two simple shapes. Glue these on in two rows. (2) On a second piece of paper, have each student draw a horizon line and some diagonals converging at a point on this line. Using the same simple shapes as in (1), ask them to solve the problem of duplicating the composition illustrated on the right.

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EXPERIMENTS WITH LIGHT

EXPERIMENT #1 – REFLECTION: Materials: flashlight, ball, dark room. (1) Put the ball on a table and turn out the lights. Make sure there is no light at all. Step back. You can't see the ball because it has no light of its own. (2) Shine the flashlight on the ball. Now you can see ball clearly. Light goes from the flashlight to the ball, then bounces back from the ball to your eyes. We can see the ball only when it has REFLECTED light.

EXPERIMENT #2 – TYPES OF REFLECTION: Materials: flashlight, mirror, aluminum foil, dark room. (1) Put the mirror on a table in the dark room. (2) Shine the flashlight onto the mirror. Notice how the mirror reflects the light almost as bright as the beam itself. (3) Put a smooth piece of aluminum foil on the table and follow the same procedure. Again a lot of light will be reflected. Conclusion: From a smooth surface, light rays bounce back in the same direction. This is called REGULAR REFLECTION. (4) Now crumple the foil into a ball. Open the ball up but don't make the foil smooth and flat. Just lay it on the table all crinkled. Turn your flashlight on the rough foil. The light bounces off in all directions. Conclusion: Rough surfaces do not reflect light as evenly as smooth surfaces. This demonstrates DIFFUSE REFLECTION.

EXPERIMENT #3 – ABSORPTION: Materials: a flashlight, a piece of white paper, a piece of black paper, a dark room. (1) In a dark room, shine the light on the white paper. Hold your other hand 10-12 inches above the paper. Notice how much light is reflected from the paper to your hand. (2) Try shining the light on the black paper. This time little light is reflected to your hand. The black paper soaks up light as a sponge soaks up water. This is called ABSORPTION. White and light colors reflect light, black and dark colors ABSORB. What is cooler to wear on a hot day: a black shirt or a white shirt? Why?

EXPERIMENT #4 – CATEGORIES OF REFLECTIVE MATERIAL: Materials: A collection of objects made of different materials, a flashlight. (1) Try shining the light at each of the objects. (2) Sort them into three categories: (A) TRANSPARENT materials allow the light to go straight through them (clear glass or plastic, clean water); (B) TRANSLUCENT materials let some of the light through but scatter it. Through these everything looks blurred (frosted glass, wax or tracing paper); (C) OPAQUE materials do not let any light pass through. Since most things are opaque, this will probably be the biggest category. You cannot see anything through opaque materials (brick wall, door, heavy coat).

EXPERIMENT #5 – SPECTRUM: Fill a jar 3/4 full of water and place it on a window sill. Find the place where the SPECTRUM shows like a rainbow line on a white piece of paper held opposite. Or use a prism and a flashlight or slide projector as your light source. You will get better results if light passes through a slit in a thin piece of cardboard before it falls on the prism.

EXPERIMENT #6 – REFRACTION: Materials: a glass half-filled with water, a straw. (1) Place the straw in the glass. (2) If you look at it from the side you will see the effect of REFRACTION. The straw appears to bend at the place where it touches the surface of the water.

EXPERIMENT #7 – LIGHT BENDS: Materials: bowl, coin, water. Put coin in bottom of bowl. Move backward until coin just disappears from sight. Stand still while a friend pours water into bowl. Coin will come into view again because water bends light from coin so it travels to your eye.

EXPERIMENT #8 – LIGHT TRAVELS IN STRAIGHT LINES [RAYS]: Materials: flashlight, dark room. (1) Select two students to demonstrate. The students stand facing each other some distance apart. One aims the flashlight beam at the other. (2) Ask the student holding the flashlight to put his hand over the front of the flashlight. Some light shines around hand, but partner can no longer see the beam. (3) Sound also travels in waves, but it has different properties than light. (4) Ask one of the students to hold her hand over her mouth (without touching it) and say something in a loud voice. The other partner can will hear it because the sound of a voice will go around the hand. Unlike light, sound waves can turn corners.

EXPERIMENT #9 – LIGHT: Because light doesn't bend, when it hits an opaque object, a dark area forms behind it. This is how SHADOWS are formed.

SHADOW GAMES: Can you hide your shadow? Can you escape from your shadow? Can you shake hands with a friend's shadow if your hands are not touching? Can you catch your friend's? If you put a foot on his shadow, it's his turn to try to catch your shadow. Can you fit inside your friend's shadow? Can you jump on your friend's shadow?

EXPERIMENTS WITH COLOR

EXPERIMENT #1 – CHROMATOGRAPHY: You can separate the pigments used in colored pens. Cut a strip of blotting paper or paper towel. Use a black or dark felt-tip pen or put a spot 1/2 inch from bottom. Make the spot as dark as possible, but not too big. Hold end nearest the ink so it just dips into a dish of water. If your hand gets

tired, stick the other tip of paper to a pencil laid across the dish. The pigments will spread up the paper. Each pigment travels at a different speed and so they separate. When color reaches the top of the paper, take it out and let it dry.

You can also try this with circles of blotting paper. Dot them with several different colors of marker. Fold paper in half, then half again. Dip folded point tnto water and watch colors spread. Carefully open circle to dry.

EXPERIMENT #2 – COLORED LIGHT AND COLOR: Draw the colors of the spectrum on a piece of white cardboard. Cover the end of a flashlight with red cellophane so it produces red light. In a dark room, shine the red light onto the cardboard. Some of the colors will appear as shades of red; these reflect red light. Some will appear black; these absorb red light. Try blue cellophane.

EXPERIMENT #3 – CAMOUFLAGE COLOR: Color is vital to animals, often helping them to blend with their environment and escape predators. You can test how well this works. Cut 30 short pieces each of red and green yarn. Spread them out over a grassy area. Give students two minutes of seeking the yarn as if birds looking for caterpillars to survive. Count up at the end to see if they find more red than green. The red CONTRASTS with the color of the grass.

EXPERIMENT #4 – COLORS OF LIGHT: Materials: three flashlights; blue, red and yellow cellophane. Attach cellophane to front of flashlight with tape or rubber bands. Shine two flashlights on a white piece of paper: red + blue = purple (magenta); blue + green = greenish blue (cyan); red + green = yellow. All three together make white. We can make white light by mixing the primary colors of light.

EXPERIMENT #5 – PIGMENT COLORS: Mix primary colors of paint red, yellow, blue in pairs to make secondary colors of orange, green, purple. Mix all three to get neutral color (theoretically black). Use these six colors to make Newton's Disk below.

EXPERIMENT #6 – NEWTON'S DISK: Materials: circle of tagboard or stiff paper; paints or marker, straight pin. Draw lines to divide disk in half, then divide each half into thirds to make a total of six equal cone-shaped sections. Lightly paint each section in the following order: yellow, orange, red, violet, blue, green, yellow. Stick the pin right in the center, where all the lines cross, then into the top of a pencil eraser. Hold the pencil and snap the end of the disk to spin the disk fast. If this is done in very bright light, the disk should look white.

EXPERIMENT #7 – SCATTERING WAVELENGTHS: Materials: tall, clear container of water, 1/2 teaspoon of nondairy creamer, flashlight, screen. Add the creamer into the water; do not stir. Focus a spot of light on the glass, with a white screen on the opposite side. The particles in the water are small and uniform, so selective scattering occurs. From the side, the milk appears bluish, but the color on the screen is pink. The blues are scattered; the longer wavelengths (red) are transmitted.

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GLOSSARY

Camouflage: A coloring or pattern that matches the background and makes things hard to see.

Chromatography: Process of separating colors into parts that make them up.

Cones: Sensing cells in each eye that detect red, green, and blue. There are more than 6 million cones in each eye, and they work only with light.

Diffraction of light: The effect caused by passing light through a row of narrow openings. This splits up the light into the colors of the spectrum.

Light waves: The waves by which light travels.

Pigment: A coloring material.

Primary color: A color which cannot be made by mixing other colors. The primary colors of pigments are yellow, red (magenta) and blue (cyan). The primary colors of light are red, green, and blue. All other colors can be made by mixing the primary colors.

Prism: A solid shape made of glass or other transparent material, which has equal and parallel ends (often triangular) and sides with parallel edges. Usually a triangular piece of glass, but can be anything that refracts light; can be a drop of water.

Reflection: The bouncing back of rays of light from a surface.

Refraction: The bending of light. When light passes from one substance to another, it usually changes direction. It bends because light travels faster through some substances than others.

Rods: Sensing cells in the eye that detect black, gray, and white in dim to bright light. Humans have 123 million rods.

Spectrum: The band of colors into which a ray of light may be split up.

Transparent: Allowing light to pass through.

Wave: A way in which energy travels from one place to another.

Wavelength: The distance from the crest of one wave to the crest of the next. Each different color of visible light has a different wavelength. Red is fastest, violet is slowest.

White light: Light from the sun or an artificial source, such as an electric light bulb, which looks white but is in fact made up of the colors of the spectrum.

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